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RESPONSE OF PHOSPHORUS LEVELS, FYM, AND NANO ZINC ON GROWTH AND BIOMASS ACCUMULATION OF WHEAT

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ABSTRACT

A field experiment was conducted during the rabi seasons of 2023–24 and 2024–25 at the NRM Block, College of Agriculture Farm, BUAT Banda (U.P.), to evaluate the effect of Phosphorus levels, FYM, and Nano Zinc application under integrated nutrient management (INM) on growth and biomass accumulation of wheat. The study comprised nine treatments arranged in a randomized block design with three replications. Treatments include different combinations of 100% recommended dose of fertilizers (RDF) with farmyard manure (FYM), bio-consortia, and nano zinc foliar sprays. The objective of this study was to assess the influence of these combinations on plant height, tiller number, and dry matter accumulation in wheat crop.The integration of RDF with FYM, bio-consortia, and nano zinc (T_7) consistently responded the highest performance in all growth parameters. At harvest stage, T_7 treatment showed the tallest plants (114.47 cm), maximum tiller number (7.48 tillers plant^{-1}), and maximum dry matter accumulation (196.90 g plant^{-1}). After T7 treatment, T8 and T3 treatment performed closely in these growth attributes. In contrast, the absolute control (T1) consistently recorded the lowest values for growth attributes across all parameters. Significant differences in growth parameters were observed from 60 DAS onwards, observations also supported by low coefficient of variation (CV%) and statistically significant critical differences (CD at 5%).The performance of treatment T7, was found superior due to improved nutrient availability, better soil microbial activity, and enhanced zinc response via nano zinc application. Overall, the study suggest that adoption of integrated nutrient management with nano- zinc fertilizer, is a effective nutrient management strategy for improving growth, tiller count, and biomass accumulation in wheat under field conditions.

Keywords : Wheat, Nano Zinc, Bio-consortia, FYM, Dry Matter, Growth Parameters.

Introduction

Wheat serves as a staple food in the traditional wheat-growing regions of northwest and central India. The yields vary significantly across different regions. In the irrigated northern states of Punjab, Haryana, and western Uttar Pradesh, wheat yields are notably higher, ranging from 4.5 to 5.0 tons per hectare. In contrast, the western and central states, including Gujarat, Rajasthan, Madhya Pradesh, Bihar, and parts of Uttar Pradesh, experience relatively lower yields, typically between 1.5 to 3.0 tons per hectare. This disparity in productivity highlights the impact of the cultivation of wheat in India is significantly influenced by irrigation and regional factors, as highlighted in the Grain and Feed Annual report of 2019. Globally, wheat stands out as a leading crop, occupying approximately 267 million hectares with an annual production of around

902 million tonnes. Within India, Uttar Pradesh emerges as a key player in wheat production, ranking first in both wheat area, covering about 9.75 million hectares, and production, yielding 31.88 million tonnes during the 2017-18 period, according to Borse *et al.* (2019). However, the intensive cultivation of crops like wheat, aimed at achieving high annual productivity, often results in substantial nutrient removal from the soil. This can lead to a significant imbalance when the replenishment of these nutrients through chemical fertilizers and manures does not keep pace with their removal. The scenario is further exacerbated by the global energy crisis and the escalating prices of chemical fertilizers, which not only pose economic challenges to farmers but also contribute to deteriorating soil health. The sustainability of wheat cultivation and soil health thus becomes a major concern, underscoring the need for balanced nutrient management practices that can support long-term agricultural productivity and soil fertility. A decline in wheat production exacerbates the hardships faced by the population and severely impacts the country's economy. Among the key factors influencing wheat yield, fertilizers are particularly main limiting factor, as they provide essential nutrients that directly affect crop productivity and quality. Effective use of fertilizers can help to optimize wheat production, thereby supporting food security and economic stability. Conversely, inadequate fertilizer application or imbalanced nutrient management can lead to reduced yields, further compounding the challenges posed by decreased wheat production. Thus, fertilizers play a pivotal role in ensuring sustainable wheat cultivation and mitigating the adverse effects of production shortfalls. Application of fertilizer at proper time, in balance proportion and with appropriate method had a positive impact on crop yield (Nasir *et al.,* 1992; Alam *et al.,* 2002). Phosphorous deficiency is a yield reducing factor in soil nutrient reserve, particularly soils high in calcium carbonate, which reduces phosphorous solubility (Ibrikei *et al.,* 2005). Phosphorus fertilizer plays a crucial role in crop production due to its importance in plant growth and development. However, phosphorus has limited mobility in soil, typically moving only 3-5 cm after application. This restricted mobility results in a significant portion of applied phosphorus may become fixed in the soil, making it less available to plants. It's estimated that only about 15-20% of applied phosphorus is readily available to crops. Therefore, the research for efficient phosphorus management to optimize fertilizer use and crop productivity is essential (Camargo *et al.,* 2000). Placement of phosphorus fertilizer in close proximity to wheat seeds through banding has been proved to be more effective than broadcast application, particularly during the early stages of crop growth. This targeted application allows the young plants to access phosphorus more readily, promoting healthier root development and overall growth. By positioning the fertilizer near the seeds, band application optimizes nutrient availability when the plants need it most, potentially leading to improved crop establishment and yield. This method can be especially beneficial in soils with low phosphorus availability or in conditions where phosphorus mobility is limited (Matar & Brown, 1989). Significantly maximum yield of grain in wheat has been obtained by many researchers with optimum use of P fertilizer (Grant *et al.,* 1989). The amount of fertilizer used typically depends on several factors, including the type of crop, soil nutritional status, yield goals, and irrigation or rain-fed conditions. However, due to a lack of awareness about the benefits of organic practices, many farmers have resorted to the indiscriminate use of inorganic chemical fertilizers to maintain crop productivity. This trend, characterized by the excessive reliance on chemical fertilizers without incorporating organic nutrient sources, has contributed to the deterioration of soil health. The imbalance in nutrient management not only affects soil fertility but also has broader implications for sustainable agriculture and environmental health. One of the best way to optimize crop productivity and maintain a healthy ecosystem is INM, it can be achieved by providing the necessary conditions of nutrient cycling and greater use of bio-fertilizers and organics. Hence, the integrated nutrient management (INM) has emerged as a vital strategy in agricultural economies, especially in developing nations like India where ensuring food and nutritional security is of utmost importance. By adopting a holistic approach that combines organic and inorganic nutrient sources, INM optimizes crop yields as well as maintain soil health. This balanced method enables farmers to boost crop productivity, lower production costs, and enhance soil fertility. As a result, INM plays a crucial role in promoting sustainable agricultural practices, addressing food security challenges, and fostering environmental sustainability. By integrating diverse nutrient sources, farmers can develop efficient and balanced nutrient management systems that support long-term agricultural productivity.

Materials and Methods

The field experiment was conducted at NRM, Block, CoA farm, BUAT Banda (U.P.), during *rabi* season of 2023-24 and 2024-25. The experiment was laid out in randomized block design consisting of nine treatment combinations *viz.,* T_1 Absolute control, T_2 100% RDF (NPK)(120:60:40), T_3 100%RDF + Nano Zinc (2 Foliar spray), T_4 100%RDF (NK) + Phosphorus (75%) + Nano Zinc (2 Foliar spray),T_5 100%RDF(NK) + Phosphorus (50%) + Nano Zinc (2 Foliar spray), T_6 100% RDF (NPK) + FYM (5 ton),T_7 100% RDF (NPK) + 5 ton FYM + Bio-consortia + Nano Zinc (2 Foliar spray), T_8 100%RDF (NK) + Phosphorus (75%) + 5ton FYM + Bio-consortia + Nano Zinc (2 Foliar spray),T_9 100%RDF (NK) + Phosphorus (50%) + 5 ton FYM + Bio-consortia + Nano Zinc (2 Foliar spray), which was replicated three times. A uniform dose of 120:60:40 NPK Kg ha^{-1} was applied to all treatments. Full dose of phosphorous as per treatments and potassium along with half of the nitrogen were applied as basal while remaining half dose of nitrogen was top-dressed at first irrigation.

Results and Discussion

The influence of integrated nutrient management (INM) practices on the growth parameters of wheat was evident from the results presented in Table 1. The application of the recommended dose of fertilizers (120:60:40 NPK kg ha^{-1}), in combination with various phosphorous doses, resulted in significant differences in plant height across all growth stages during both years of the study.

Plant height increased progressively from 30 days after sowing (DAS) to harvest under all treatments. At 30 DAS, the tallest plants were recorded in treatment T7 (100% RDF (NPK) + 5 t ha^{-1} FYM + bio-consortia + two foliar sprays of nano zinc), with a pooled height of 22.42 cm. This was followed by T8 (21.94 cm) and T3 (21.24 cm). In contrast, the lowest plant height was observed in the absolute control (T1), with a pooled value of 17.13 cm. This trend remained consistent across subsequent stages (60 DAS, 90 DAS, and at harvest).At the time of harvest, T7 continued to show the maximum plant height (114.47 cm), closely followed by T8 (113.63 cm) and T3 (113.43 cm). On the other hand, T1 maintained the lowest height at 95.57 cm. These findings clearly demonstrate the beneficial impact of integrating chemical fertilizers with organic amendments and micronutrient applications, particularly nano zinc, in improving the vegetative growth of wheat. Statistical analysis revealed that the standard error (SEm±) ranged from 0.98 to 3.30, while the critical difference (CD at 5%) was statistically significant from 60 DAS onwards. The coefficient of variation (CV%) ranged from 2.07% to 8.92%, indicating acceptable levels of experimental variability and a high degree of precision. These results align well with previous studies by Sharma *et al.* (2020) and Kumar *et al*. (2018), who also reported improved growth parameters in wheat under integrated nutrient management regimes. The inclusion of FYM likely enhanced soil structure and microbial activity, while the bio-consortia may have facilitated better nutrient solubilization and uptake. Moreover, foliar applications of nano zinc may have contributed to improved micronutrient availability during critical growth phases. The statistically significant increase in plant height observed after 60 DAS, showed the importance of nutrient availability during the tillering and stem elongation phases. This suggests that INM practices not only support early growth but also sustain plant development throughout the growing season. Overall, the study highlights the effectiveness of integrated nutrient management in enhancing the vegetative growth of wheat. The consistent superiority of T7 across all growth stages demonstrates the potential of combining inorganic fertilizers, organic manures, microbial inoculants, and nano-technological interventions for improving wheat productivity under field conditions.

Number of Tillers per Plant

The number of tillers per plant was significantly influenced by integrated nutrient management (INM) practices across all growth stages. At 30 days after sowing (DAS), the highest tiller count was recorded under treatment T7 (100% RDF + 5 t ha^{-1} FYM + bio-consortia + two foliar sprays of nano zinc), with a pooled value of 2.47, which progressively increased to 7.48 tillers per plant at harvest. Treatments T8 (7.38) and T3 (6.96) also recorded enhanced tiller numbers, whereas the absolute control (T1) consistently produced the lowest tiller count across all observation points, with a pooled value of 2.63 at harvest. The more number of tiller observed under T7 and T8 may be attributed to the synergistic effect of balanced application of chemical fertilizers, organic manure, bio-consortia, and nano-zinc micronutrient supplementation. The application of FYM and microbial inoculants likely to be contributed to improved rhizosphere conditions and nutrient mineralization, while nano zinc enhanced the availability of micronutrients during key vegetative

phases, resulting in better root proliferation and tiller initiation. Statistical analysis revealed that the critical difference (CD at 5%) was significant from 60 DAS onwards, highlighting the effectiveness of the treatments during the active vegetative stages. The coefficient of variation (CV%) ranged from 6.13% to 10.51%, indicating reliable experimental precision. These results are in line with earlier findings by Kumar *et al.* (2019) and Yadav *et al.* (2021), who reported that integrated use of FYM and inorganic fertilizers significantly improved tiller number in wheat due to enhanced nutrient uptake and soil fertility. Similarly, Ramesh *et al*. (2018) emphasized the role of bio-fertilizers and micronutrients in stimulating root growth and hormonal activity, thereby promoting more number of tillers. The better response of nano zinc application are supported by Shivay *et al.* (2020), who reported increased physiological efficiency and vegetative growth in cereals due to use of nano zinc foliar sprays. The consistent superiority of T7 throughout the crop cycle underscores the importance of a holistic nutrient management approach that integrates chemical, organic, and microbial inputs along with micronutrient interventions to optimize tiller formation and enhance wheat productivity under field conditions.

Dry matter accumulation per plant

Dry matter accumulation plant^{-1} was progressively influenced by integrated nutrient management (INM) practices across all growth stages of the wheat crop. At 30 days after sowing (DAS), Treatment T7 (100% RDF + 5 t ha^{-1} FYM + bio-consortia + two foliar sprays of nano zinc) recorded the highest pooled dry matter accumulation (2.48 g plant^{-1}), followed closely by T3 (2.43 g plant^{-1}) and T8 (2.41 g plant^{-1}). However, the lowest value was observed under the absolute control T1 (2.24 g plant^{-1}). Despite the numerical differences, statistical analysis revealed that differences at this stage were not significant. By 60 DAS, significant differences in dry matter accumulation became evident. T7 continued to lead with a pooled accumulation of 11.79 g plant^{-1}, followed by T8 (11.45 g plant^{-1}) and T3 (10.63 g plant^{-1}), whereas the absolute control treatment T1 registered only 6.29 g plant^{-1}. The critical difference (CD) at the 5% level was 0.71, and the coefficient of variation (CV%) was 4.74, indicating moderate variability and strong treatment effects. This trend continued at 90 DAS, where T7 (46.66 g plant^{-1}), T8 (46.46 g plant^{-1}), and T3 (44.54 g plant^{-1}) showed significantly higher dry matter accumulation compared to T1 (34.83 g plant^{-1}), with a CD of 1.75 and a CV of 2.37%. At harvest, T7 again recorded the maximum dry matter accumulation (196.90 g plant^{-1}), followed by T8 (190.70 g plant^{-1}) and T3 (177.95 g plant^{-1}), while the absolute control (T1) remained the lowest (111.10 g plant^{-1}). Statistical analysis at harvest confirmed a significant difference (CD at 5% = 0.05) with a very low CV% of 1.82, indicating high experimental reliability. These results clearly demonstrate that integrated nutrient management had a profound and consistent influence on dry matter accumulation throughout the wheat crop's life cycle. Treatments consisted of combined use of chemical fertilizers (RDF), organic manure (FYM), bio-consortia, and nano zinc foliar applications particularly T7 and T8 showed superior performance across all growth stages. The observed results are in consistent with earlier findings as reported by Kumar *et al*. (2018) and Singh *et al.* (2020), who showed that INM strategies significantly improve biomass accumulation in wheat by enhancing nutrient synchronization and soil biological activity. The superior performance of T7 can be ascribed to the synergistic effects of balanced macronutrient supply, increased micronutrient availability through nano zinc foliar applications, and improved microbial dynamics from the application of FYM and bio-inoculants. Furthermore, the increased dry matter accumulation from 60 DAS onward reflects enhanced root activity and efficient nutrient uptake during the critical tillering and panicle initiation stages. These observations are aligned with the work of Meena *et al*. (2019), who highlighted the role of integrated nutrient inputs in sustaining crop growth during peak nutrient demand periods. Similarly, Shivay *et al.* (2021) reported that nano zinc nutrient applications significantly improved foliar nutrient uptake and biomass accumulation in cereals. Overall, the consistent and significant improvement in dry matter accumulation in INM-based treatments, particularly those supplemented with nano based fertilizers, confirms that integrated nutrient management is a highly effective strategy for maximizing vegetative biomass and enhancing the yield potential of wheat under sustainable production systems.

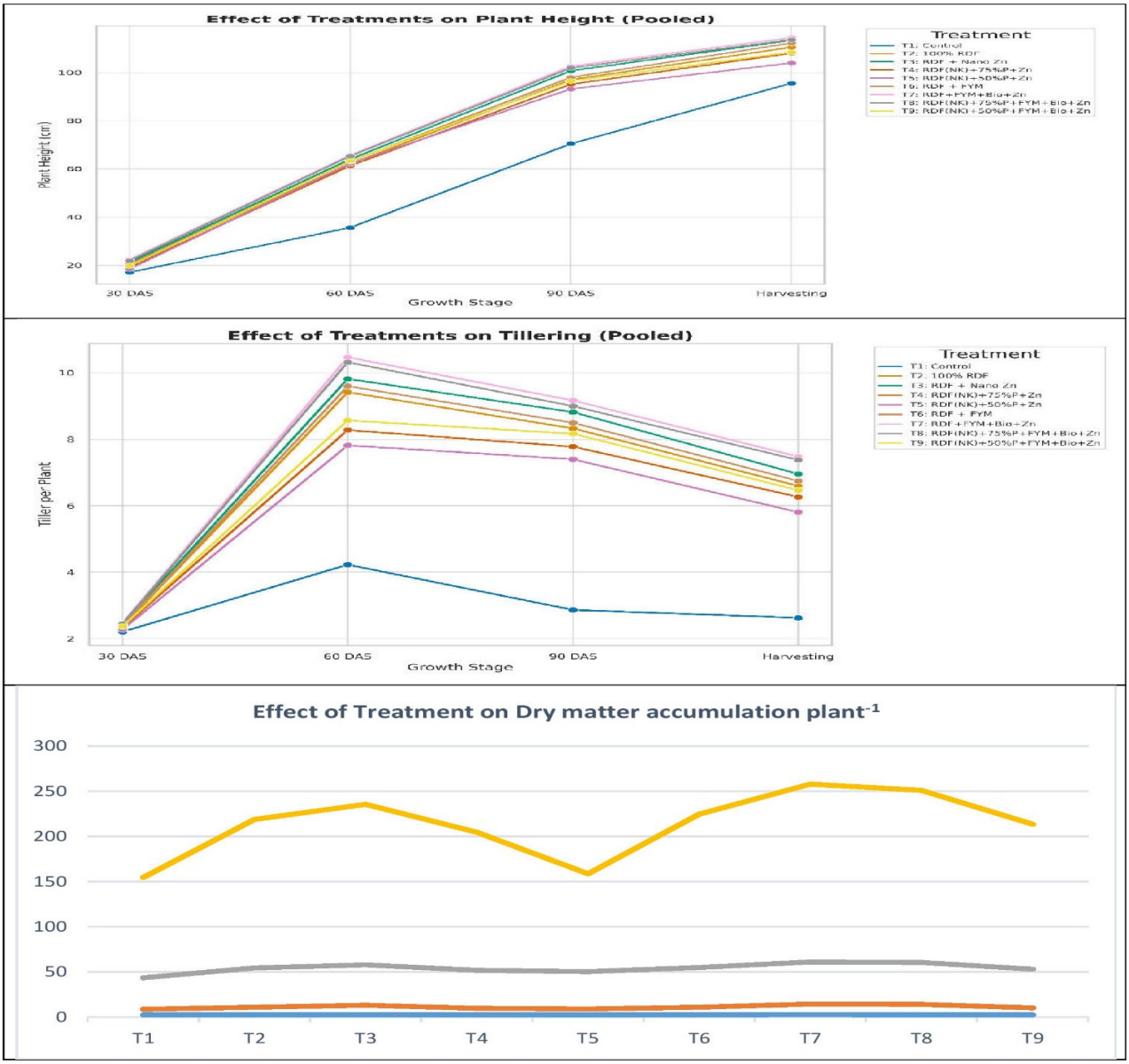

Fig. 1: Effect of treatment on growth parameter of wheat

Table 1 : Response of variable phosphorous doses on plant height, tiller per plant and dry matter accumulation at 30, 60, 90 DAS and at harvest stage in wheat crop

Treatment Symbol	Treatment Combination	Growth parameters											
		Plant height				Tiller plant^{-1}				Dry matter accumulation plant^{-1}			
		30 DAS	60 DAS	90 DAS	AT Harvest	30 DAS	60 DAS	90 DAS	At Harvest	30 DAS	60 DAS	90 DAS	AT Harvest
T_1	Absolute control	17.13	35.67	70.46	95.57	2.21	4.23	2.87	2.63	2.24	6.29	34.83	111.10
T_2	100% RDF (NPK)(120:60:40)	20.25	62.11	97.05	110.54	2.38	9.42	8.33	6.60	2.39	8.49	43.42	164.45
T_3	100% RDF + Nano Zinc (2 Foliar spray)	21.24	64.05	100.75	113.43	2.44	9.82	8.82	6.96	2.43	10.63	44.54	177.95
T_4	100% RDF (NK) + Phosphorus (75%) + Nano Zinc (2 Foliar spray)	19.31	61.32	95.14	108.05	2.34	8.28	7.78	6.27	2.33	7.28	41.98	152.95
T_5	100% RDF (NK) + Phosphorus (50%) + Nano Zinc (2 Foliar spray)	18.54	62.26	93.20	104.01	2.28	7.82	7.40	5..81	2.27	6.59	41.32	108.25

T_6	100% RDF (NPK) + FYM (5 ton)	20.46	63.14	98.01	112.26	2.40	9.60	8.50	6.75	2.39	8.48	43.93	169.75
T_7	100% RDF (NPK) + 5 ton FYM + Bio-consortia + Nano Zinc (2 Foliar spray)	22.42	65.68	102.62	114.47	2.47	10.47	9.17	7.48	2.48	11.79	46.66	196.90
T_8	100%RDF (NK) + Phosphorus (75%) + 5ton FYM + Bio-consortia + Nano Zinc (2 Foliar spray)	21.94	65.35	101.93	113.63	2.45	10.32	9.00	7.38	2.41	11.45	46.46	190.70
T_9	100%RDF (NK) + Phosphorus (50%) + 5 ton FYM + Bio-consortia + Nano Zinc (2 Foliar spray)	19.74	63.34	96.51	108.44	2.37	8.57	8.17	6.47	2.36	7.75	42.77	160.45
S.E.m ±		1.03	2.3	2.9	1.30	0.08	0.39	0.24	0.25	0.09	0.23	0.58	1.66
C.D.		NS	7.01	8.7	3.91	NS	1.17	0.73	0.77	NS	0.71	1.75	5.00
(P=0.05) CV(%)		8.92	6.72	5.34	2.07	6.13	7.76	5.46	7.11	7.30	4.74	2.37	1.82

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